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OF

The Engineering Society

OF

THE LEHIGH UNIVERSITY.

DECEMBER, 1886.

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ABSTRACT OF PROCEEDINGS.

September 23, 1886.—President LaDoo in the chair, and ten members present. No papers were read, but the welfare of the Society was discussed. The following gentlemen from '88 were elected: Messrs. Zollinger, Stevenson, Parker, Glover, Morrow, Breigel and Mr. Reisler, '87. The President appointed the following committees: On Mathematics—Messrs. Snyder, Richards and Woods; on Astronomy—Messrs. Reisler and Kittrell; on Mechanics, Bridges, etc—Messrs. Pollak, Phillips and Richards; on Chemistry—Messrs. Stevens, Jones and Polk; on Mines—Messrs. Stackhouse and Breinig; on Surveying—Messrs. Witmer, Bonnot, Cunningham and Pratt; on Machines—Messrs. Wiechardt, Howard and Scull; on Manufacturing — Messrs. Terrell and Dravo, and on Hydraulics—Mr. Hittell.

October 7.—The President was in the chair, and thirteen members present. Messrs. Shipman, Domenich and Diven were elected members. Mr. Hittell read an interesting paper on "The Teredo," and exhibited specimens of wood which had been attacked by it. Mr. Howard explained the difference between Injectors and Inspirators, showing a model of each. Mr. Wiechardt exhibited and explained a contrivance for mechanically drawing gear-teeth.

October 21.—The President in the chair, and fifteen members present. The following gentlemen from '88 were elected to membership: Messrs. Cornelius, Shane, Hart, George Davis, Brad-

ford, Bonzano, C. H. Miller, G. P. Miller, Rickert, McClintic, Raynor, and Mr. Pettinos, '87.

The following honorary members were elected: Messrs. Miller, F. P. Spaulding and G. F. Duck. Mr. Breinig read a paper entitled "Is the Interior of the Earth a Molten Mass?" Mr. Wiechardt gave a discussion on Rolling Friction, deducing the formula, $F = f\frac{R}{r}$.

The following amendment to the Constitution was offered by Mr. Jones. Art. II., Sec. 4, to read: The students in the schools of Engineering, after attaining their Junior year, may become active members, etc.

November 1.—The President, Mr. LaDoo, in the chair, and thirty-one members present. Mr. Mott, '88, was elected a member of the Society. Mr. Zollinger was elected as the Junior Editor of the Journal. Mr. Stevens read a paper on "Manganese" and exhibited blue-prints of the new spiegel furnace now being erected at the Lehigh Zinc Works. Prof. Merriman gave a very interesting description of the "Great Walking Survey," for which a vote of thanks was tendered by the Society.

November 18.—Messrs. H. Palmer, Frescoln and Focht were elected. Papers were read by Mr. Witmer on "Centers for Arches," by Mr. Terrell on "The Wootten Firebox," and by Prof. Williams on "Mine Accidents Due to Coal Dust," with an account of the accident in the Pocahontas Mine, and description of the mine. The Society tendered the Professor a vote of thanks.

MASON D. PRATT, *Secretary.*

THE TEREDO.

I can best give you an idea of this mollusk from the naturalist's point of view by quoting from a recent writer upon this subject, Dr. Stearns, of the Smithsonian Institute.

The shipworms are *bivalves*, that is to say, the complete shell is in two pieces, although one can form no idea of the Teredo from them, as the shelly part is but an insignificant portion of the entire animal, as you will learn from the following:

"The Teredo * * * consists of a long and nearly gelatinous, worm-like body, without rings or segments, terminating at

one end in a pair of * * * valves that somewhat resemble the two halves of a split nutshell which has had a large slice cut off at each side, and at the other, in a pair of symmetrical shelly paddles with handles of different lengths, which close this extremity at the will of the animal. The open part of the bivalve shell is placed at the farther end, and receives a circular disk of a fleshy or rather muscular nature, which may be termed the foot; this is the broadest and widest part. Inside each valve is seen a curved process, like a bill-hook, that projects from the hinge at a right angle. The shell covers and protects the mouth, palps, liver and other delicate organs. The body tapers gradually to the outer or nearer end, where it becomes quite small and attenuated; it contains the gullet, intestine and gills, which form at the outward point two cylindrical tubes, mostly of unequal length. The larger tube takes in infusoria or similar animalcules, which constitute the food of the Teredo, as well as imbibes water charged with air for the purpose of respiration and keeping the whole fabric moist, while the smaller tube is employed in the ejection of the water which has been exhausted or deprived of aeriferous qualities, and also serves to get rid of the woody pulp that is excavated by the Teredo. Both tubes form a kind of hydraulic machine. At the base of each lies one of the paddles often termed 'pallets.' * * *

"When the Teredo is alarmed, or not feeding, it withdraws its tubes into the neck of its sheath or shelly cylinder; and the pallets, which had been previously kept pressed against the sides, then spring forward and close the opening so as to form an efficacious barrier against all foes," etc.

There are both males and females; the latter bring forth young by eggs. These eggs are developed at any time, but especially in June. The Teredo can, and does to a great extent, hibernate in wood, and in the Spring can go through all the phenomena of reproduction; viz., fecundate, form eggs, develop and expel young. Within four days after expulsion the mollusk has passed from its embryonic state and is capable of entering woods.

The boring instrument has been thought by some to be the fleshy foot, and by others, the mouth extending over the shells, while yet others have held that the boring is done by the shells. The holders of the first two methods have only theories for their reasons, while those that maintain the last way have the satisfaction of knowing that boring *can* at least be done with the shells, as these

two facts will show: (1) Under the microscope, the striæ on the convex side of the shells are made up of crystal-toothed saws composed of teeth $\frac{1}{1000}$ths. of an inch in height and the same distance apart; the rows or sets of teeth are at right angles so as to cross-cut. (2) A piece of shell fastened to a stick with gum has been pressed, revolving it in the meantime, against a soft piece of wood. In four and one-half hours a hole thirty millimeters in depth was bored.

The cutting is done by a peculiar advancing and rotary motion of the shells. It is claimed that the feet, or pallets, hold on to the sides of the wooden tunnel and thus help the Teredo in this rotary motion. As the mollusk advances itself, it passes the pulverized wood through its body (generally through the shorter pallet) as a white substance, depositing at the same time the concentric rings of the calcareous lining of the gallery. This lining is very brittle, though hard. No two galleries have ever been known to cross each other, a film of wood, often very thin, always separating them.

The Teredos enter the timbers of a structure a little above the bottom of the body of water and almost invariably work upward along the grain, only turning aside for galleries of other Teredos, knots, or nails, or any other hard substance. They do not go higher than the mean between the ebb and flood tides. The hole in the wood made by the young Teredo's entrance is quite small, the appearance of the infested timber is quite deceptive, giving but little evidence of the size or number of the burrows or extent of the ravages within. After awhile the interior is so honeycombed that a slight blow will shatter the structure.

Among the conditions for life and the propagation of its young the Teredo requires a clear, pure water, having a certain percentage of saltiness—it does not thrive in brackish waters. This last fact accounts for its inability to live near the discharge holes of sewers, water-closet drains, etc. An adult Teredo left in wood but taken from the water, can live for about twenty-four hours; left in water and taken from wood, from three to four hours; and, if taken from both, dies in from one to two hours.

True to that law of nature which makes many animals destroy each other, the Teredo has an enemy in the Annelide. It was the fortune of a writer on this subject to see one of these Annelides eat up a Teredo larger than itself, leaving nothing but the shells.

In certain sea-ports of different parts of the world there are small crustaceans which cut away, either along or across the grain, any wood that the Teredo may leave.

The ravages of the Teredo involve the engineering problem of building, safely and economically, in waters infested with them. As we can not kill them off or drive them away, we must prepare our timbers so as to resist their ravages. I have divided into three classes, though not at all rigorously, the methods which prevent the depredations of the Teredo for a longer or shorter time; viz., natural, mechanical and chemical, which are more or less dependent upon and blend into each other.

Natural: (*a*) There are certain kinds of wood which are said to be almost entirely able to withstand the Teredo. They are the jarrah, or mahogany, and red gum woods of Southwestern Australia, and the palmetto wood of our Southern States. (*b*) Along our Gulf Coast, where barnacles abound, they immediately fasten themselves upon the timber in such quantities and in so close a proximity, as to leave no place for the Teredo to enter. The attachment of the barnacles may be hastened by charring the timber, which in itself will be preventive by keeping the Teredo from gaining what might be called a foot-hold.

Mechanical: (*a*) Copper sheathing needs no explanation. In ordinary cases this is entirely too expensive. (*b*) Driving the wood full of iron nails, which, by the action of the sea-water will form a coating impassable to the Teredo. This is tedious in preparation and is not reliable; a vigorous jar will knock the coating off. (The methods under Natural and Mechanical are rarely, if ever, used now-a-days for permanent structures; they might be used for works of a temporary character, as the scaffolding about a bridge pier.)

Chemical: It has been almost conclusively proved that the Teredo is proof against the chemical poisons; all preparations involving that principle have signally failed. At the annual meeting of the A. S. C. E. in June, 1885, the Committee on the Preservation of Timber, after five years of deliberation and exhaustive research and experiment, said in their report under the head of *Selection of Preserving Process:* "If the timber is to be put in sea-water and exposed to the ravages of the Teredo, or similar marine workers, creosote, or 'dead oil' is the only antiseptic in our knowledge; and the amount of this oil used depends upon the situation and consequent temperature of the water as already

mentioned. The quality as well as quantity of the oil is important." Further under the caption of *Will it Pay?*: "With piles likely to be attacked by the Teredo, and, as in Southern waters, be cut off in one or two years, creosoting *must* be resorted to to avoid great waste of capital."

The process of creosoting consists in injecting the timber with hot creosote oil in a closed tube under pressure. It was invented by a Mr. John Bethell, of England. This creosote is the oil of tar, and is a powerful coagulator of the albumen in the wood, furnishing a water-proof covering to the fibers and preventing putrefaction by virtue of its antiseptic properties. As a preventive against the Teredo, English engineers consider ten to twelve pounds to the cubic foot sufficient, but French engineers consider nineteen pounds necessary. The English practice is to use seasoned timber, while in our country the mode is to use fresh timber, first however, thoroughly steaming it in order to vaporize all moisture. This steaming process is being introduced abroad, even in seasoned timber. To perfectly protect timber against the Teredo, from ten to twenty pounds per cubic foot must be used, depending upon the exposure. As creosote costs one cent per pound, the final cost would be from twelve to twenty dollars per 1,000 feet B. M. JOHN B. HITTELL.

EARLY SURVEYING INSTRUMENTS.

The first surveying problem which would naturally present itself to a fixed community, would be the dividing of its lands, and fixing boundaries; for this would follow directly from the cultivation of the soil. This was especially the case in that part of Egypt subject to the overflow of the Nile. The water depositing sediment, would of course gradually efface or cover up the old boundary marks, and it was, therefore, necessary to have these marks established in such a way that they might be readily retraced. In Egypt, then, we may say, surveying had its origin; and from Egypt the Romans obtained their forms of surveying instruments.

There were two principal problems which a surveyor of those days had to solve; he had to establish a basis, and then from this conduct his operations of dividing the land or running the boundaries. For this there were two instruments in use. The one for

the establishment of the basis, which was in every case the meridian, was termed the gnomon ; the one for taking up details, the groma. In one of Hero's books, the "Dioptric," we find a description of an instrument called a "dioptra." In this are taught methods of leveling, of running a straight line between two points not intervisible, of measuring the breadth of a river, of finding the distance of the observer's station from an inaccessible point, recovering lost boundary marks, etc.

The Dioptra is not mentioned by the Roman writers, but it has been ascertained that it was an Alexandrian improvement on the "groma," and below is given a general comparison between the two, taken from "Die Römischen Grundsteuervermessungen," by E. Stöber.

"Upon a support supplied with a plumb-line, in order to set the instrument vertically, rests a horizontal disc and upon the latter a straight-edge, which is provided at the ends with little plates having notches in them to sight through. The straight-edge may be turned upon the disc both in a horizontal and vertical plane by means of gearing. Two small projections on the plate mark the points distant 90° from the original position of the straight-edge, so that the turning off of right angles requires no skill. The plumb-line on the support of the dioptra fulfills its purpose by means of a vertical line marked on the lower part of the support, along which the plumb-line has to hang when the instrument is vertical.

A water level is attached to the upper movable part in order to place the instrument in a horizontal position. This consists of a small copper tube to which are fastened two small glass tubes about twelve fingers in length, in which the water has to stand at a certain mark.

The "groma" was almost identical with our present form of the surveyor's cross. It consisted of an iron frame, pointed at the bottom, upon which rested two straight-edges at right angles to each other.

The dioptra was set up by means of a plumb-line and a water level : this was done in the groma by four plumb-lines which hung down from the four corners of the cross and covered one another in the diagonals as well as in any two adjacent sides.

While with the dioptra a right angle was turned off as described above, in the groma this angle was constant owing to the fixed position of the arms.

It will be seen at a glance that the groma was a primitive instrument, while the dioptra with its arm movable, through gearing, already gave evidence of an instrument for measuring any angle; it was in fact the germ from which grew the astrolabium, the theodolite, and our angle measurers of to-day.

The instruments which the Roman surveyors used were the following:

(1) The surveyor's poles; straight poles provided with iron points, used for the same purpose as the surveyor's poles of to-day.

(2) The surveyor's rod; *decempca portica*, was a wooden rod with divisions marked on it, and was used for measuring straight lines. When measuring sloping ground a plumb-line was suspended from one end of the rod and the latter moved until the plumb-line hung perpendicular to it or as near so as could be judged with the eye.

(3) The hydrostatic balance. To both ends of a rod about twenty feet long were fastened a pair of arms on which two lines were drawn parallel to each other and perpendicular to a third line drawn the length of the rod. Plumb-lines were suspended along these lines, and the rod moved until the parallel arms were vertical according to the plumb-lines. When this was the case the line along the face of the rod was horizontal. But as it was impossible to use a plumb-line in windy weather, a groove of uniform depth was cut along the face of the rod and filled with water; the whole instrument being then shifted until the water attained a uniform depth throughout the groove.

The method of using this instrument was as follows: First the rod was placed in a horizontal position. Then measurements were taken to find how much higher one vertical arm was above the ground than the other, this giving the difference in elevation. In this manner they measured the rise and fall of the ground.

(4) The groma; this has been already described.

(5) The gnomon (index of the sun dial).

This was also one of the first instruments used in astronomy. Its invention is accredited to one Anaximander, who observed the solstices and probably also the inclination of the ecliptic to the equator. The gnomon consisted of an iron rod pointed at the upper end and was always set up vertically upon a horizontal plane. The shadow which the gnomon cast at noon was measured and from the relation of the length of the rod and shadow, the angle which the rays of the sun made with the horizon was

obtained. The use of the gnomon by the Roman surveyors was confined to determining the meridian.

This much for the surveying instruments of the ancients. We have seen that they produced an instrument which had some of the elements of our theodolite, but it lacked the one vital part, the graduated circle. The earlier observers did indeed use divided circles which they called astrolabes, armillas, etc., for the purpose of surveying; but they were, generally speaking, very rude. The quadrant was employed in all accurate surveys up to the latter half of the last century, although Roëmer had shown by reason and example, the superiority of the entire circle. The first instance of a survey on a considerable scale conducted with an entire circle was that of Zealand in 1762–1778; the horizontal circle there used being two feet in diameter.

For astronomical purposes the circle was used as far back as the time of Ptolemy, who calls it from its use a solstitial circle. It consisted of an outer fixed circle and an inner rotary one. The inner circle seems to have been employed as the most accurate method of giving a rotary motion to the line of collimation, concentric with the divided circle. The angles were read by means of pointers. The solstitial circle was the best contrived instrument of which we find any account, until the time of Roëmer.

It will be readily seen, that after the invention of the telescope the essentials of the present theodolite were at once at hand. To whom the honor of first making the combination belongs, is a matter of doubt. The engineer's transit is merely a modification of the theodolite, and is an American idea. J. S. S.

NOTES ON PROFESSOR MERRIMAN'S ADDRESS ON "THE GREAT WALKING SURVEY."

Delivered before the Engineering Society of the Lehigh University, Thursday, November 4, 1886.

Owners of lands derive their titles from those who held them before. The Moravian Congregation bought their land on which their colony, Bethlehem, was founded, from William Penn. William Penn acquired his right, first, through the charter of 1681 from the King of England, and second, by purchase from the Indians. It is the story of the latter transaction which is the subject of this address: The Great Walking Survey.

In 1682 William Penn arrived in Pennsylvania and at once adopted a wise and benevolent policy—that of buying his lands from the natives. In 1686 a deed of purchase was made from the Indians for the land on which Philadelphia now stands and its neighborhood. In the same year a deed was executed for land along the Delaware River . . . . . and extending North as far as a man could walk in a day and a half. It was not, however, carried into effect—not walked out. But settlers kept pouring in and land was sold, causing great indignation among the Indians. In 1718 another deed was executed giving all lands bounded on the East by the Delaware, on the West by the Susquehanna and on the North by the Lehigh Hills; but land was even settled upon North of this, causing much dissatisfaction among the Indians. In 1736 another deed was executed for a part of the land in the great valley between the South and the Blue Mountains which was called the Tulpehocken purchase. In 1737 the Indians were persuaded to execute a deed with the Government confirming the deed of 1686. The latter could not be found, but a copy was procured from England and the Indians consented to it. The Western boundary was understood to be the Tulpehocken lands along the Schuylkill. The Northern boundary was to be determined by a one-and-a-half day's walk North from a point where Wrightstown now stands. From the end of the walk a line was to be drawn perpendicularly to the Delaware River for the Northern boundary. On the twenty-fifth of August, 1737, the deed was signed. Advertisements for the fastest walker were immediately published, offering a reward of £5 and 500 acres of land. Edward Marshall presented himself and was accepted, and about one month later, on the twentieth of September, the walk was made. Preparations for the walk were made along an Indian trail through the Lakeweki region (meaning forks), and passing through Bethlehem. At sunrise Edw. Marshall stood with his hand against the white oak-tree and started on his walk. He was accompanied by the sheriff of Bucks County and others on horse-back, and by several Indians. Two of the Indians gave out before the morning was over. They said: "You walk too fast; no sit down to smoke." Before noon the party took dinner at Durham Furnace. During the afternoon they passed near Bethlehem; crossing the Lehigh at an old Indian ford near Nisky, from which point they crossed the country to Catasauqua, thence along the river and arrived at

nightfall at the Lehigh Gap, the rest of the Indians having given out some time before. There the party spent the night near an Indian village. Next morning the Indians were invited to go with them, but they refused, saying that all the good land had been passed and they did not care how much farther they went. The "walk" terminated at a point near Penn Haven (some say at White Haven). The next thing to be done was to draw a perpendicular from the line of the walk to the Delaware River. This ran nearly parallel to the Pokopoko Mountains. The length of the "walk" was about 70 miles.

The dissatisfaction of the Lenape Indians at the whole affair was very great; so great, that five years later, in 1742, it was feared that the Indians would come upon the settlers and massacre them. And the Government sent to the Iroquois to come and settle the matter. The result was that some of the Lenape chiefs removed to Wyoming. But many remained, and continued dissatisfied. Serious trouble ensued after 1750. When the French War broke out the Indians joined the French and massacred the settlers in several villages. The story goes that Edw. Marshall and his family were killed at this time by them. The address concluded with a brief account of the history, habits and character of the Lenape tribe of Indians.

IS THE INTERIOR OF THE EARTH A MOLTEN MASS?

Provided the nebular theory be true, and since it is generally regarded as so, the earth must at one time have been but a small portion of an immense field of incandescent vapor, originally endowed with a slow rotary motion, accelerated by some means or other. Contraction took place. The motion of the particles was increased, and consequently the centrifugal force was augmented until finally rings were thrown off or separated from the central portion.

These rings, in turn, were separated into fragments, of which one is the earth. This great contraction in such a mass revolving through space, was evidently accompanied by an enormous condensation and thus developed much heat. The earth then at one time was in an entirely incandescent state. Ever since then secular cooling has been going on, refrigeration probably taking place by circulating radiation followed by conduction.

It is hardly necessary to point out the present signs of subterrannean heat. It may be mentioned that there are at present three hundred active volcanoes throughout the earth, an almost innumerable number of hot-springs, and that an increase of depth in the earth is followed by a rise in temperature. Earthquakes probably owe their origin to it.

Astronomers, for obvious reasons, first advocated the theory of the earth's interior having had a temperature much higher than at present. Geologists confirmed this by subsequent discovery; besides, they reasoned that the earth must still for a greater part exist in this molten state—that, in fact, the earth consisted of a molten interior and a crust of about fifty miles in thickness. To substantiate such a statement, those believing in it give the following reasons:

1. A descent into the earth through either natural or artificial causeways is always accompanied by an increase of temperature for a corresponding increase of depth. On an average we find this to be one degree Fahrenheit for every sixty-feet of descent. At this rate the temperature of boiling water is found at a depth of two and four-tenths (2.4) miles, and the melting point of platinum (3080° F.) at a depth of thirty-five miles. Making some allowances, we can say that the crust is fifty miles thick and the remainder molten.

2. The existence of volcanoes, active and inactive, over probably all parts of the earth, shows that it was and is yet the seat of an enormous mass of molten material.

3. The numerous earthquakes, affecting large areas, indicate a thin and flexible crust.

4. The remarkable uniformity of character, shown by volcanic material wherever found, points strongly toward one large common source and not to local seats of high temperature.

One of the first to doubt that the earth existed under such conditions was Hopkins, an Englishman, who mathematically tried to prove that such a condition—a thin crust and a molten interior—was non-conformable to the earth's precession and nutation.

By comparing a homogeneous earth with a shell and a molten interior, with one that was heterogeneous, he concluded from results obtained that the earth in order to withstand these disturbing forces must have a crust at least eight hundred to one thousand miles thick and even suggested entire solidity.

Later, Thompson took up this same matter and by even a more rigorous mathematical application practically arrived at the same conclusion. He also stated, that if the earth's crust consisted of steel three hundred miles thick, yet would it yield to the various forces acting on it to such an extent as to nearly equal that of an india-rubber earth having the dimensions of the terrestrial sphere.

Pratt proves the same thing in a different manner. He took for example a mountain in Hindostan whose height was two and one-half (2.5) miles; distance from the level of the sea to the highest point measured at sea level, forty miles; and length of most elevated portion, two hundred and thirty miles. Taking a unit section of this mountain and the earth's crust underneath, and letting $A\ B\ M\ C\ D\ c\ m\ b\ A$ represent an average section of the mountain; $A\ B = 40$ miles: $B\ C = 230$ miles; $Bb = Cc = 2.5$ miles; mn a vertical line $= t$; Ar parallel to $mn = t'$; arc $AM = a$; area $AbmM = K$; $G =$ its center of gravity; $rg = k$, perpendicular to Gg, a vertical line; $re = y$, perpendicular to the line he which is perpendicular to mn at its middle point, h. hk is a line passing through the middle point, of mn and Ar.

Now, the crust Mr is held in equilibrium by its weight, the downward pressure of MA—the overlying mountain mass—the upward pressure of the fluid interior, and the force of adhesion at the joints mn and Ar.

Since, by hypothesis, the crust has been formed by a solidification of the fluid formerly occupying its place, the density of the crust may be assumed as that of the fluid formerly occupying the same point. Hence the weight of the crust, Mr, equals the upward pressure of the fluid interior. The weight of mountain-mass above tends to break this crust which is sustained by the adhesion at the joints An and Mn. If any part sinks, the joints will open. And if any sinking takes place at one of these joints another opening will occur. Let the point m sink; then will the joint An open as well as some joint to the left of n. Taking r for the center of moments the equation of forces acting on Mr is

$Kk = Cty + \frac{1}{2}\ Ctt' = Ct\,[r - \frac{1}{2}\,t + h - (r - t')\cos a] + \frac{1}{2}\ Ct'^2$ in which $C =$ the length of rock of unit cross-section, the weight of which equals the average force of adhesion on a unit of surface. The greatest limit of C is considered to be one-fifth ($\frac{1}{5}$) of a mile.

$$2\ Kk = [t'^2 + tt' \cos a - t^2 + 2\,(r \text{ vers } a + h)\,t]\ C.$$

Taking the case of m being at c, then $k = rg = 255$ miles; $a = 5° 19'$; $\cos a = 9957$; r vers $a = 17.2$ miles. Taking $K = CabB = 230 \times 2.5 = 575$ square miles, and $h = 2.5$ miles, then

$$t'^2 + 2\,tt' - t^2 + 39.4\,t = 1466250 = (1214)^2 \text{ miles, nearly.}$$

If t be very small t' equals 1212 miles, nearly. Also, t' can not be small otherwise t^2 would be negative. If $t = t'$ then each is greater than eight hundred (800) miles. In regard to the density of the crust as compared with that of the fluid from which it was formed, if the density of the crust is the greater then the tendency of the crust to break will be greater than assumed in the problem. Should, however, the crust's density be less than that of the fluid the reverse would occur. In any case a fracture is liable to take place unless the crust is very thick.

Since no elevation or depression takes place we conclude that the earth's crust is very thick.

Again, it is not probable that a rise in temperature should continue uniformly with a corresponding increase of depth. The increase of heat at the rate of 1° F. for every sixty feet of depth might be augmented by the proximity to volcanic regions, or be due to chemical action, or friction of working tools. What takes place at depths beyond those yet attained by man it is difficult to ascertain. It is reasonable to think that at great depths the overlying material produces such a tremendous pressure that the rocks in expanding, consequent to a high temperature, have to overcome this pressure, and by thus raising their fusing point materially increase the calculated depth—so that possibly we may find no fluid state at all. Now; the hardest rocks we know of are varieties of granite, the compressive strength of which is about ten thousand (10,000) pounds per square inch; but, at the center of the earth this pressure is in the neighborhood of thirty millions of pounds per square inch. This tremendous pressure, being so far beyond our comprehension, casts a doubt into our minds as to whether rocks are formed from molten masses under heavy pressure and whether the reverse might not occur.

The cause of igneous action to-day is thought to be due to a removal of pressure over certain large areas covered over by comparatively thin crusts, that is, lakes of hot material yet remain scattered throughout the earth not far below its surface. This is one explanation given for it. Another is, that rocks are

liquefied at comparatively small depths below the earth's surface by the incessant rubbing and shifting of rocks due to alterations in temperature. With the aid of thermodynamics it was shown that such disturbances produced enough heat for volcanic action.

A third theory given as the probable condition of the earth is that it consists of a central portion surrounded by a molten mass in turn enveloped by a cooled shell, or surface. This theory is mainly a combination of the other two given above, and was advanced by some geologists when the first theory no longer held true and the second seemed to be inconsistent with geological formation.

As a whole, it is plainly evident that our knowledge on such a subject must be limited, mainly argumentative, and almost wholly partake of an inferential nature. Science has not yet reached that state of perfection which would, in its material use, greatly enhance the value of our speculative theories in this skeptical age of ours. Since actual observation is impossible, we, therefore, can hardly do more than conjecture the present condition of things within the earth.

R. S. Breinig.

COAL DUST AS AN EXPLOSIVE AGENT, WITH AN APPLICATION TO THE POCAHONTAS MINE DISASTER.

Address delivered before the Society, by Professor Edward H. Williams, Jr.

Accidents from explosion have been a feature of coal mining since the origin of that industry. At first they were uniformly attributed to fire-damp, but, as efforts were made to systematize mine superintendence and prevent a recurrence of accidents from known causes, by a removal of those causes or an attempt to neutralize their effect, it was found that, in a number of cases, fire-damp was wanting or failed to exist in suitable amounts. The eyes of mining experts were opened to the presence of an unknown agent, and the object of the present paper will be to show the progress of the investigations to ascertain the nature and force of this agent, and then to see if those investigations can account for the explosion in the Pocahontas Mine in 1884. The literature of the subject is acquiring bulky proportions, but

those who desire to study it can find it outlined in the *Transactions of the American Institute of Mining Engineers*, Vol. XIII., pp. 523, *et seq.*, or in the issues of the *Engineering News* for October, 1886.

An explosion in the Walesend Colliery (England) in 1803 was the first where it was noticed that the victims were burned by sparks of ignited dust which accompanied the explosive current. In 1845, Faraday, who was one of a committee to investigate an explosion occurring in the preceding Fall, reported that dust had greatly increased the power of the fire-damp. The establishment of this principle by so eminent an authority directed more attention to the subject of coal dust, and it was accepted as an intensifier of gas in an explosion. The occurrence of accidents, under conditions that seemed to prevent the presence of fire-damp, started the question as to whether dust were not something more than an adjunct. From 1861 to the present day experiments have been made on varying scales by advocates of various theories and, where care was taken with such experiments, and their number was sufficiently large, it seemed to be proven that fire-damp, in some cases, need not be present. The explosions at Minneapolis in 1878, whereby the Washburn Flouring Mills were destroyed, showed that fine carbonaceous dust was in itself a violent explosive. In 1880, Professor Abel reported that the presence of a small amount of fire-damp would make even inert dusts dangerous, but that very small percentages were necessary with all dusts before they would be explosive. Of the great government commissions, the Prussian has made by far the most careful and thorough investigation of the subject, and their report claims that coal dust not only elongates the flame of a "blown-out" shot, but that, when ignited by such a shot, some varieties of dusts will give rise to explosive phenomena. From this it is shown that dust, in the absence of fire-damp, may become dangerous.

Dusts are produced in dry mines in small amounts by the breaking down of coal, and soft or bituminous coal produces more than anthracite because it contains a charcoal-like substance called "soot, mother of coal," etc. The greater part of the dust is produced in the gangway from the pernicious habit of ballasting the track with coal slack, or from neglecting to keep it clean when rock-ballasted. Whether the coal is placed there, or whether it is shaken from the cars on their passage from the

rooms to daylight, it is trodden fine by the constant passage of men and teams as they make their regular trips; the impalpable portion raised in a thick cloud is given to the air current which traverses the gangways with considerable velocity, and deposited on the sides and floors of the rooms as the current becomes slackened. If the dust would remain in the gangway it would be harmless, but the air current drops it where it can be stirred up by "blown-out" shots and mixed with the smoke-laden air of the "tight" headings of rooms or gangways. The use of black powder is more dangerous in such a case than that of dynamite when the latter is completely burned, as the gases from burning the former, in an explosion, contain nearly twenty per cent. of combustible ingredients. In many cascs coal-slack is used for tamping the charges and in many instances the dust will elongate the flame from explosion to an alarming extent.

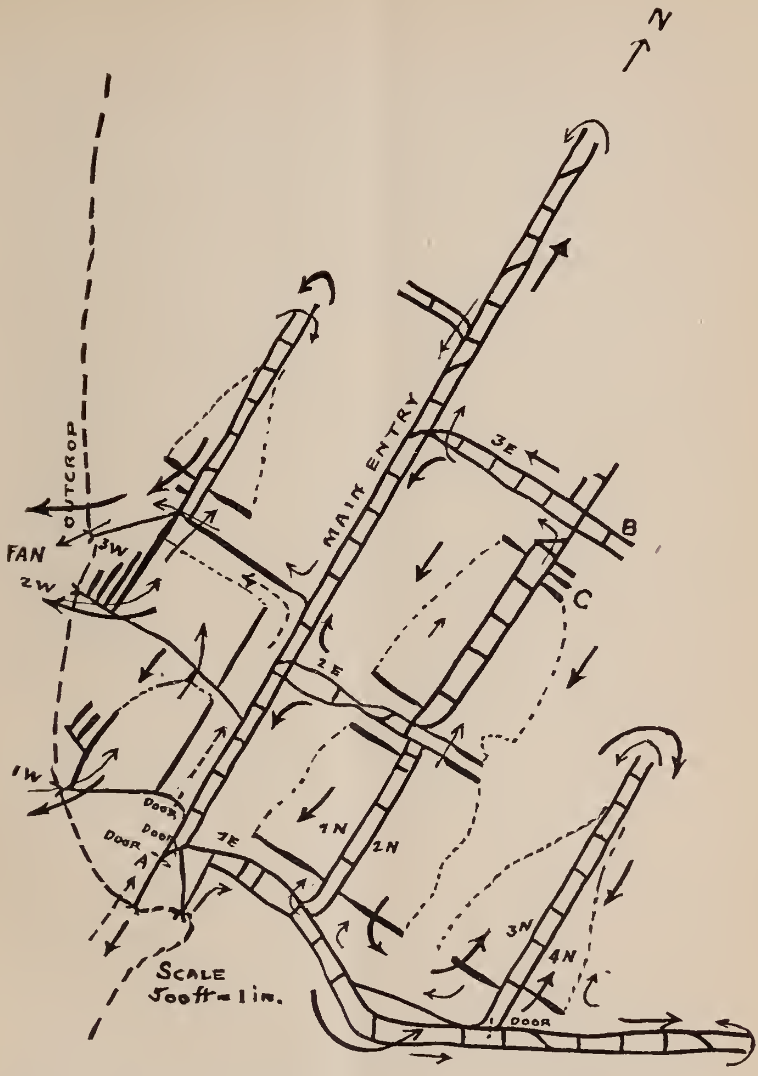
As all dusts do not act alike, it seemed to me probable that an investigation of the relative temperatures at which coals gave up their volatile ingredients might throw some light upon their explosive nature. As it had been settled that coals averaging twenty per cent. of such ingredients were most intense in their action, a number of coals from dry mines were obtained and Mr. H. B. Douglas, E.M., in 1884 began a series of tests. These were too few to conclusively prove anything, but, after successfully flashing all the samples, it was found that a tendency certainly exists in coals of the above group, which give up their volatile constituents at the lowest temperatures to form the most explosive dusts. The matter is still being pursued and it is hoped that the study of a larger number of samples will give a more decided result. If such be the case, an impalpable dust from a coal giving up its gas readily will tend to increase the area of a flame and, under favorable conditions, such a dust would readily give sufficient gas to form a mixture that would propagate an explosion to its very extremities.

The coal from the Pocahontas Mine contains much mineral charcoal; is tough and requires much work to break down; averages about twenty per cent. of volatile matter, and gives off sixty per cent. of that amount at a temperature below dull redness (500° C.). The committee appointed by the Institute of Mining Engineers to investigate the Pocahontas explosion (the author being one) found that the market was good and the coal in such demand that the mine was worked day and night—the

day-shift numbering three hundred and the night-shift over one hundred men. The labor was largely from the immediate neighborhood (colored and white) and was not so highly skilled as that employed in older fields, as was shown by the number of shot-holes used to drive narrow work, and by the testimony of the mine boss and others examined. In many cases the usual under-cut was not made, and the ignorant men tried to blast from the solid. In many cases the holes had to be " set " for the more ignorant. A new mine like this is compact, and the mining is carried on in a circumscribed area so that the proportion of smoke-laden air from working rooms to the total air in the mine was greater than is common in older and larger mines, and, consequently, the proportion of gases of explosion in the air would be greater, even under the same conditions. With ignorant men using too much powder the proportion would be greater. From Saturday night till Monday morning the mine had time to clear itself, at other times there was no cessation of working and firing. During the day-shift there was estimated to be 70,000 cubic feet of air per minute sent through by a Murphy ventilator, while at night, during the week of explosion at least, the mine was forced to depend upon natural causes for its ventilation by the locking open of the door (A) at the foot of the main entry. The plain, light, arrows, show the usual course of the air current ; the dotted ones the course on the night-shift : the plain, heavy, ones the course taken by the explosive current.

The dotted light line shows the area occupied by the rooms : the heavy dotted line the outcrop.

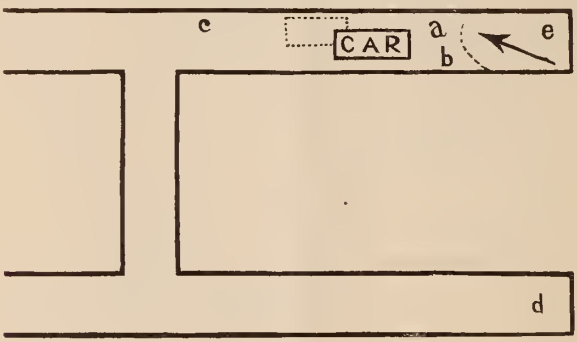
By the opening of this door (A) the part east of the main entry was practically unventilated during the night-shift and, on the night in question, had been open from 6 o'clock P. M. till the time of the explosion at 1.30. During these seven hours seventy-five or eighty men were working from twenty-five to twenty-eight rooms and the headings of eight entries and airways. The faces of four of these latter average 80 feet from the course of the air at the nearest cross-cut : of the other four, the face nearest the current was distant from it 152 feet, and the others, 170, 208 and 224 feet. Three rooms (C) next to the upper gangway were "tight" and their faces over 80 feet from an air-current passing at right angles to their length. The air was led through the workings without forming splits and after taking up the smoke and dust from 4N, 3N, and 1 and 2N, it was led past the three rooms (C) and



turned sharply to the left in the airway of 3E without going near the faces of the gangways at B. Part of the gangways (1 E, and 3 and 4N) was ballasted with slate; the rest of the mine with coal slack. This fact must be noted as it affected the character of the explosive current as it reached those parts of the mine. The mine was very dry and, with one exception, officers and men deny the presence of fire-damp.

There existed, therefore, a coal, dry, full of mineral charcoal, tough and hard to break down, and possessing twenty per cent.

of volatile matter that was given off at a low temperature ; a tendency to form an abundance of dust from the coal-ballasted roads ; an ignorant class of men who burned more gunpowder than was necessary, and an absence of ventilation through the greater part of the mine. On Wednesday evening, March 12, 1884, at 5 o'clock, the night-shift went to work ; the three hundred or more men of the day-shift left the mine which had been continuously worked for eighty-two hours ; the door A was locked open and the ventilating current stopped to the east of the main entry, and the smoke and dust from one hundred rooms and entries allowed to drift slowly as the imperfect natural ventilation would carry them ; the faces of the rooms (C) and the entries at (B) had been practically unventilated for several days. With coal dust of such a nature in such an atmosphere, only a slight elevation of temperature, such as a "blown-out" shot, or the explosion of a keg of powder was needed to produce a serious accident. From time to time there had been prolongations of the flame from shots and in some cases the flame had extended over 100 feet. Something of this nature occurred at 1.30 on Thursday morning and within a few seconds every man had been killed of one hundred and twenty or more who were at work.



The evidences are that two explosions occurred in the upper heading of 3E, marked B. Two men were working there and had successfully fired a shot which threw down a mass of coal that extended for fifteen feet from the face. A car had been run in and one of the men had nearly filled it, and was loading it at the time of the explosion, Fig. 2, (b). Near him (a) was sitting a man smoking a pipe. It may have been his partner, or the partner of the man working the airway (d), and his partner may have been at (c) where their box stood and where a keg of

powder had exploded. The burning and mangling of the bodies rendered it difficult to identify them as many were new men, and the record book of the night-boss was destroyed with its owner by the explosion. It was thought that four men were at work in these two places, but only three bodies were found. The first explosion may have been from the face (e), and the second towards it, as was shown by the appearance of the place after it was over. The man at (b) was found at (e) lying upon his back with his arms extended above his head and his hands clenched as if in pain. On lifting him it was found that before he had been thrown backward he had been struck in the back by a hot flame that had torn the muscles of the back and thrown them with the fragments of his clothing forward over his shoulders. The man at (a) had been struck by the same hot flame and crushed into the coal and away from (b). In both cases there were evidences of burns from a clean gas and not so much from powder or dust, as the men were not "badly blackened up." The car was found at the dotted line, badly wrecked. The wood-work (oak) was splintered and the iron-work (axles, etc.), bent and crushed. The distance traveled by the car was small, but the force must have been tremendous. At (c) was found the wreck of the box used by those working this entry. All that remained were a few fragments of wood from the box and part of the top and of a hoop of a powder keg which had exploded. By far the greater force, as shown in the heading, was the one coming from the face in the direction of the arrow, and yet it is strange that the effect upon the car should be so powerful while it was slight, in comparison, upon the men. The force toward the face did not seem to touch the car and, while it passed over the man at (a) without touching him, as he was partially screened by the wrecked car, it caught the man at (b) and dashed him against the face. From this it seems that he had not had time to fall from the first explosion before he was caught by the second. If it were not for the peculiar wounds of this man, it might be supposed that the first force came from the exploding powder-keg, unless we can imagine the force from the exploding powder to be slight and not to reach to the face except to cause a condensation that was followed by a reaction from the mixture of gases and smoke with which it was filled. In that case the last force that threw the men toward the face would have been caused by the reaction from the larger explosion as it gained force by going south. That explosive reac-

tions occurred, is proven by the appearance of the working-faces of (c) Fig. 1) and of every close heading in the mine. Even in the portions 3 and 4N, where there was generally heat without force, there were signs that the hot flame came rolling into every room without a cross-heading and came only so far, for the coking suddenly stops when insufficient ventilation had failed to move the smoke fiom the shots, and an explosion of this mixture has invariably occurred. From the universal repetition of this fact it may be accepted that it was the case in the heading first spoken of, as it was over 200 feet from the ventilating current and had been worked continuously since the Monday previous: the current, at best, was loaded with the dust and smoke of all the workings east of the main entry; the missing man may have been sitting at his box eating his midnight lunch (as such seemed to be the case generally), and the powder-keg may have had its bottom out, as was seen in other cases. The exploded keg destroyed the box and killed the man, it fired the gases of explosion and dust in the close heading and these generated such a force that the fragments of the box and of the man were caught by the current that tore up the track and swept away the ballast as thoroughly as if a broom had been used. At any rate, the explosion gathered force from the dust-ballasted area of 1N and 2N, and there is evidence of explosion in nearly all the rooms, as the track is torn up and props knocked down. The part of the current that turned east to 3 and 4N traversed an area of rock-ballast and met a fresher current of air that allowed the dust in the mixture to burn. There is little force, but a heat so intense that the coked dust is found adhering to the props in crusts of an inch in thickness, and the solid coal is covered with the curls of its own coke wherever the wave touched. Analyses of this coke show a variation of four or five per cent. in the specimens from floor and roof as would be natural. The men in 1N and 2N were badly mangled as well as burned, and the mules were dashed about so that, in one case, the hoofs were knocked off. In 3N and 4N the action was swift and intensely hot as the bodies were intact, but terribly burned and covered with crusts of coked dust. In the former section the force of the current tore the cars from the breasts and heaped them in a confused, broken mass at the turn in 2E. A wheel and axle from one of them was carried over 150 feet through a narrow cross-cut; around two sharp corners, and was left broken and twisted out of shape.

From the evidence of outsiders who were awake at the time, and from the position of the bodies inside, it may be estimated that from one-half to three-quarters of a minute covered the period of the explosion. The reports from the various openings came within one and one-half seconds of one another. Some of the victims had heard the first shock and had run thirty feet; one had had time to cover his head with his coat and tuck the ends under his arms to keep off the fire; the greatest number were caught at work or resting during the midnight lunch time: one was found in the attitude of eating. Those in the parts nearest the main entry, when not dashed at once to pieces, had evidently tried to get away; those in 3N and 4N had been caught by the silent and swift flame and were found as it had come upon them unaware, or had only time to put their hands before their faces, as a shield, and were found thus, as they had fallen.

The evidences are that the dust was amply sufficient to have caused the disaster. It was flashed with a common lamp by one of the committee on the side pillar of one of the rooms. It was reported that a former miner had said he would like to make gunpowder with such dust instead of charcoal. With such a dust in abundance; with an abundance of the unburned gases of exploding gunpowder and with a number of totally unventilated headings, there should be no disagreement in the verdict that the Pocahontas disaster was due to dust alone.

CENTERS FOR ARCHES.

There is nothing connected with the construction of stone or brick arches which requires more careful attention on the part of the builders than the centers—it matters not what the shape or span, or for what particular purpose the arch be intended. Aside from the choice of material and the care with which other parts of the construction are performed, the settlement and ultimate stability of the arch decidedly depends on the framing, setting and striking of the centers. The yielding of a brace of improper dimensions or a slight change in the shape of the frame caused by an ill-seasoned timber, may result in so changing the shape of the intrados as to endanger the safety of the arch. It must be the object of the engineer in all large-spanned arches, to determine by what combination of beams and by what system of bracing

the greatest strength and stiffness may be secured, combined with lightness and economy of materials.

When in position the centers are placed about 5 to 7 feet center to center and are known as ribs. Pieces of board or plank, called laggins, are placed horizontally upon them, on which rest the voussoirs until the key-stone is inserted, when the arch becomes self-supporting. The frame-work of the center consists of short beams which are cut on the outer edge to form parts of a curve, and when put in place they unite to form the same curve as the intrados of the arch. These are held in place by horizontal tie-beams, struts, ties and braces, the arrangement, number and dimensions of which will depend upon the shape and span of the arch as well as the number and position of the points of support.

Experience shows that whatever be the shape or span, the arrangement of the ribs in the form of a polygon is the best in every case. This shape is acquired by the arrangement of the short beams or back-pieces, which usually consist of two or more pieces of plank firmly nailed together and abutting end to end, forming a joint in the direction of the radius of curvature of the arch. It is obvious that the strains to which the centers are subjected arise solely from the pressure upon the back-pieces and laggins. Therefore the strains depend upon the span and curve of the arch and the thickness and weight of the voussoirs which rest upon the centering. All the voussoirs from one springing line to the other do not, however, press upon the frames. This depends very greatly upon the degree of curvature of the arch. In a full-centered arch the voussoirs exert no pressure upon the frames for a considerable distance above each springing line, but when the point is reached where the stones begin to exert a pressure upon the frames, such pressure increases very rapidly as we approach the crown and reaches its maximum intensity just before the key-stone course is driven into place. Those voussoirs which lie near the springing-plane and exert no pressure upon the laggins and back-pieces are all situated within the angle of repose—in other words, the voussoirs do not begin to press upon the centering until we meet one whose lower joint makes so great an angle with the horizontal as to cause it to slide under the force of gravity.

For ordinary cut stone, the angle of repose of a full-centered arch has been found by experiment to be about 30°; but if the stone be laid in full mortar it will be very nearly 45°. The num-

ber of stones, then, that will load the center-frame, taking the angle of repose at 30°, will depend entirely upon the form of the curve given to the intrados. For example, in a full-center, an oval and a flat segmental arch, having the same number of voussiors, it is plain that the number of stones which do not press upon the laggins will be greatest in the first-mentioned arch, less in the second and still less in the third. Those stones which do press upon the laggins do not do so with their entire weight, owing to the friction of the surfaces of contact which the weight of the stone is compelled to overcome.

According to Rankine the total weight of each stone which presses upon the laggins is to the weight with which they actually load the frame as an arc of 60° is to twice its sine less the same angle, or the relation may be thus expressed:—

Let W = total weight of voussiors which rest on centering and w = weight with which they load centering.

Then we have $W : w :: \text{arc } 60° : 2 \sin 60° — \text{arc } 60°$,

or $$w = \frac{W(2 \sin 60° — \text{arc } 60°)}{\text{arc } 66°}$$

Now let the radius be divided into any number of equal parts, say $r = 15000$. The circumference will then contain 94248 and the arc of 60° — 15708. The sine of the arc of 60° will be $r \times \frac{1}{3} \sqrt{3} = r \times .8660 = 12990$.

Substituting these values in the above equation we have

$$W : w :: 15708 : 2 \times 12990 — 15708,$$

which gives a ratio of 3 to 2, nearly.

We therefore conclude that about $\frac{2}{3}$ of the weight of those stones which lie without the angle of repose actually press upon the laggins; and taking into account the 60° contained in the angles of repose on both sides, we find that about $\frac{2}{3} \times \frac{2}{3} = \frac{4}{9}$ of the gross weight of the arch expresses the load of the centers. The case is entirely similar with arches which are not full-centered. In order, then, to determine the gross weight of tl.at portion of the arch which presses on the back-pieces and laggins and causes stresses in the frame-work of the centers, it is only necessary to know the number of voussoirs, their volume and weight per cubic foot. If the centers are subject to other stresses besides those caused by the voussoirs, as is sometimes the case in tunneling where the timbering is removed before the key-stone course is driven, such additional stresses must be provided for.

The direction and intensity of strains caused by the voussoirs may easily be found by resorting to parallelogram of forces.

For example, the weight of any arch-stone, or any number of arch-stones, which acts vertically downward through its center of gravity, may be resolved into two components, one of which will be normal to the lower radial joint of the arch and will represent in magnitude and direction the weight which is *not* supported by the rib, but which is resisted by the lower part of the arch and finally by the abutment, and the other in the direction of the radius of curvature of the intrados representing in magnitude and direction the weight which must be resisted by the centering.

The strains then take the direction of the radius of curvature of the intrados. Now, to find the position of the beams which are to withstand these strains, also their number and dimensions, is next required. It is evident that a horizontal beam loaded at its middle will offer its least resistance to the load. If, now, one end of the beam be raised so that the direction of strain is oblique to the fibers of the beam, the resistance in the latter case will be to that in the former as the cosine of the angle made by the direction of the strain and the fibers of wood is to sine 90° or 1. It should follow that when the angle between the beam and strain is zero the resistance becomes infinite, and if it were not for the compressibility and certain other physical causes such would be the case. However this may be, the beam is certain to be strongest in the direction of its fibers, hence the greatest stiffness and strength will be gained when the principal pieces are placed in the direction of the strains; that is, in the direction of the radius of curvature of the arch. The practical application of this arrangement of beams is, however, restricted to small arches, because when timbers are 30 or 40 feet long it fails utterly. For while a beam of 10 feet long will offer great resistance to compression in the direction of its fibers, a beam 40 feet long would be sure to bend and require bracing. In order, therefore, to arrive at an arrangement which will adapt itself to large arches, if we resolve the radial stresses of two symmetrical portions of the arch, with respect to a vertical plane through the center of the arch and in the direction of its length, into horizontal and vertical components, these components will represent the direction of three beams, one horizontal spanning the arch and supported at each end by a vertical beam. According to Drinker on Tunneling, this horizontal beam is placed about 45° up the

arch, in practice. The voussoirs above this tie-beam are then supported by another horizontal tie-beam upheld by small vertical beams abutting on the lower tie.

Now, then, knowing the pressure exerted on the center, and being able to calculate the pressure upon any segment thereof; also, having decided upon the number and arrangement of members, the strains may be found either analytically or by the graphical method. After determining the stresses the members may be proportioned with Gordon's formula, using a factor of safety of 4 to 6.

The centering should be slightly higher in the middle than the intended height of the finished arch, in order to allow for deflection. By experience the amount of deflection is found to be $\frac{1}{400}$ of the radius of curvature. The centering must, therefore, be made $\frac{1}{400}$ of r higher at the crown than the finished arch is intended. When the key-stone course has been driven the striking of the centers must be deferred for some days, or even weeks, in order to give the cement time to settle properly. It has been found by experience, however, that it is well to very slightly withdraw the centering soon after the arch is finished, in order to allow for the deflection before the cement is perfectly settled. A very satisfactory method, with this object in view, is to have the centering supported by means of hollow cylindrical columns filled with sand. The weight rests on the sand by means of pistons, which project into the top of the column, while the pillars rest on solid foundations. There is a small opening near the bottom of each pillar, and when the arch is ready to be decentered a small portion of the sand is left out, thus allowing the arch to deflect very gradually.

N. J. WITMER.

THE WOOTTEN FIRE BOX.

It is the aim of this paper to give a description of a recent locomotive firebox which promises to come into general favor, and to point out its advantages and disadvantages as compared with earlier types. This firebox is named after its inventor, Mr. J. E. Wootten, of the Philadelphia and Reading Railroad. It was at first intended as an economizer in fuel, being designed to burn the waste anthracite coal from the mines, and gave such excellent results that it was adopted for fast express and passenger

locomotives. The first of these locomotives were constructed at the P. & R. Shops at Reading, Pa., but have since been built both at these shops and at the Baldwin Locomotive Works.

The chief points of its construction consist in its giving a large grate area, and in the manner of bracing. The former is accomplished by extending the grate-surface over the driving wheels, which necessitates that the furnace be placed higher than in the ordinary locomotive ; this in the case of large drivers requires that the boiler also be raised, but not necessarily an equal amount. This raising of the firebox and boiler elevates the center of gravity of the locomotive, a very objectionable feature, especially with roads having curves of small radii. This raising of the boiler is in part overcome by inserting a bridge of fire-brick at the front extremity of the grate-surface, and leaving a combustion chamber between this bridge and the tube sheet, which space is made to extend lower than the grate-surface. The main object of the bridge, however, is to prevent the fuel and ashes from coming into contact with and thus cutting off the draught of hot gases from the lower tubes. A cross-section of the lower part of the chamber is an arc of a circle, and is separated from the boiler shell by two or three inches, to allow space for the circulation of the water below the chamber.

The advantage of this furnace over others is, that we obtain a much larger ratio of grate surface to heating surface. In comparing these fireboxes for fast express locomotives with those of other locomotives for the same purpose, I find this ratio for the Wootten firebox to vary between $\frac{1}{15}$ and $\frac{1}{18}$, while for others it is for the swiftest about $\frac{1}{34}$, and varies from this to $\frac{1}{60}$. The advantage of this large grate-surface is easily seen ; we can use a slower draught, which gives more time for combustion, and to obtain this slower draught we use a larger exhaust, which lessens the back pressure on the piston. In regard to this advantage of slow draught, I wish to call especial attention : to obtain high speed in the ordinary locomotive, where the ratio of grate surface to heating surface is small, the fires even with the best fuels have to be forced to such an extent that the combustion is very imperfect, the swift draught carrying off, not only unconsumed gases and hydrocarbons in the form of smoke, but also small particles of coal. The process of combustion requires either time or an intensely hot furnace, much hotter than can be obtained in the ordinary locomotive.

The method of bracing differs from that ordinarily used; in this furnace the crown-bars are entirely dispensed with and only stay-bolts are used. This lessens the liability to incrustation over the crown-sheet, since there is but little obstruction to circulation, which under the present arrangement is greater here than in any other part of the boiler, and is sufficient to carry off any loose deposits.

The following is a description and details of the Wootten firebox to one of the ten locomotives recently constructed by the Baldwin Locomotive Works for the Philadelphia & Reading road.

The firebox was 114″ long by $95\frac{7}{8}$″ wide, giving a grate-surface of about 76 square feet, with a ratio for grate area to heating surface of 1–16.7; the firebox was constructed of steel plates; the side and back plates were $\frac{5}{16}$ of an inch thick, the crown plate was $\frac{3}{8}$ of an inch thick, and the tube plate $\frac{1}{2}$ of an inch thick; the combustion chamber was 46 inches long; the bridge across the throat of the combustion chamber was built of fire-brick; the firebox and combustion chamber were stayed at the sides with seven stay-bolts and at the crown with stay-bolts with hexagonal heads. The stoking is done from the foot-plate of the tender through two fire-hole doves, these fire-holes being circular and the openings being made by flanging the plates of the firebox and casing and riveting them directly together, no ring being interposed. This is a detail now used in Europe. The only difference between these and former fireboxes of this type is, that the top of the firebox slopes to the sides only and not to the back end as heretofore. It is claimed for this method that it gives a slightly increased heating surface.

"Several interesting experiments have been recently made with locomotives using this firebox. A series were made by Mr. J. A. Coleman, for the Italian Government, during three weeks in pulling freight trains up grades that were 100 feet to the mile. The engine was built by the Philadelphia and Reading road, it was fired with coal dust scraped up from the yards and pressed into cakes, also with five different kinds of Italian lignite, which have only half the calorific power of coal. With this fuel it competed with the best engines on the continent, the French, the Belgian, and the Austrian engines; it pulled the heaviest trains that could be fastened to it, and once pulled up the entire grade with all the brakes on, blowing off steam all the while."—*American Machinist.*

It is claimed for these engines that they can run 60 miles in 42 minutes, and in case of an emergency that they can make it in even less time.

O. O. Terrell.

WE deem a few words about the JOURNAL—and especially to the Alumni about the JOURNAL—not to be inopportune.

The JOURNAL has now passed out of the experimental stage and is an assured thing. In fact, it has come to stay, to be an institution and to grow with the growth of the University. To the better insure its permanency we need the support of every member of the Alumni. We want you to support us by subscribing to the JOURNAL and, what would be still more grateful, to recognize us and the work we are trying to do by sending papers for publication.

Alumni correspondence is a thing we would like to make a feature of the JOURNAL, and any facts sent us likely to be of interest to graduates will be received with thanks. We do not think we are drawing on our imagination in the least when we say that, with the assistance of the Alumni, we can make the JOURNAL one of the leading College Engineering Journals in the country.

It is with great pleasure we acknowledge through the JOURNAL a very valuable addition to the Library of the Society in the shape of two books, "The Civil Engineers' Handbook" and "The Field Practice of Laying Out Circular Curves for Railroads," by John C. Trautwine, C.E. These are of the latest edition, 1886, printed by Wiley & Sons, New York, and E. & F. N. Spon, London, and were presented to the Society by John C. Trautwine, Jr., C.E., to whom our thanks are due.

ALUMNI NOTES.

1875.

—Prof. E. H. Williams' "Manual of Lithology" was published during the Summer. It is a neat little book of 135 pp. and can easily be carried in the pocket for use on the field.

It is designed as a concise, practical text-book in schools and colleges where the length of time devoted to this study is limited, and also for the use of practical engineers to assist them in the determination of rocks on the field.

In Part I the first chapter is devoted to general definitions, such as texture and structure; in Chapter II the principal minerals are described, and tables giving their properties, are a very useful feature.

In Part II the rocks are classified according to their physical properties, and a description of each is given, with its principal properties, mode of occurrence, etc., and in Part III a scheme for the determination of rocks is given.

1878.

—The address of Charles Bull, Secretary of the Alumni Association, is for the present 534 Broad Street, Newark, N. J.

—M. Lafon is located at Paisley, Orange County, Fla.

1881.

—Mr. T. M. Eynon, Jr., has resigned his position as instructor in Mechanical Engineering at the University; Mr. L. P. Breckenridge takes his place.

1882.

—T. J. Donahue has resigned his position as chemist for the Bethlehem Iron Company.

—L. O. Emmerich is located at Stockton with Linderman, Skeer & Co.

—E. H. Lawall is taking a special course in chemistry at Lehigh University.

1883.

—E. K. Bachman on account of ill health has resigned his position as instructor in Mineralogy and Blowpiping and gone to Lower California. F. B. Petersen, '85, has taken his place.

—G. F. Duck has been elected to the position of instructor in Mining Engineering. This is a great improvement, as formerly one man was compelled to do the work in both the departments of Mineralogy and Mining.

—E. F. Miller is now assistant instructor in Mechanical Engineering at the University.

1884.

—H. B. Douglas is with the Roane Iron Company, Rockwood, Tenn., under M. M. Duncan, Class of '80.

1885.

—H. W. Rowley is still with the Dickson Manufacturing Company, Scranton, Pa.

—John Wagner, who is with Coxe Bros. & Co., of Drifton, spent a few days in town this month.

—I. A. Heikes, formerly an editor of the JOURNAL, is with the Magnetic Iron Ore Company, Harrisville, N. Y.

1886.

—W. H. Dean is teaching in the Harry Hill Academy, Wilkes-Barre, Pa.

—F. W. Fink is with the Lehigh Valley Coal Company, and J. H. Spengler with the L. V. R. R. Co., at Wilkes-Barre.

—Mr. J. S. Siebert has returned for the Winter from Oregon, and will work on the surveys done during the Summer, in the Geologist's office, Washington, D. C.

—C. E. Clapp is studying law; R. C. Gotwald in the City Engineer's office; and M. S. Hanauer assayer for the Omaha and Grant Smelting Works; all at Omaha, Neb.

—Guadalupe de Lara and A. S. Ross are in the Southwark Foundry, Philadelphia, Pa.

—H. G. Reist, formerly president of the Engineering Society, is in the Foundry and Machine department of the Harrisburg Car Co. His address is Thirteenth and Derry Streets, Harrisburg.

—W. A. Lydon is in the City Engineer's office, Chicago.

—G. A. Ruddle is professor of Mathematics and Natural Philosophy at the Diocesan School, Reading, Pa.